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Armed Forces College of Medicine

AFCM

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DEVELOPMENT OF NERVOUS SYSTEM

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Lecture Plan



1. Part 1 (5 min) Introduction
2. Part 2 (40 min) Main lecture
3. Part 3 (5 min) Summary

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Key points



1. Formation of the neural tube [Neurulation] & its fate
2. Development of the spinal cord
3. Congenital anomalies of the spinal cord
4. Development of the brain: 1ry & 2ry brain vesicles and their fate
5. Congenital anomalies of the brain
6. Derivatives of the neural crest cells

♣Development of nervous system:

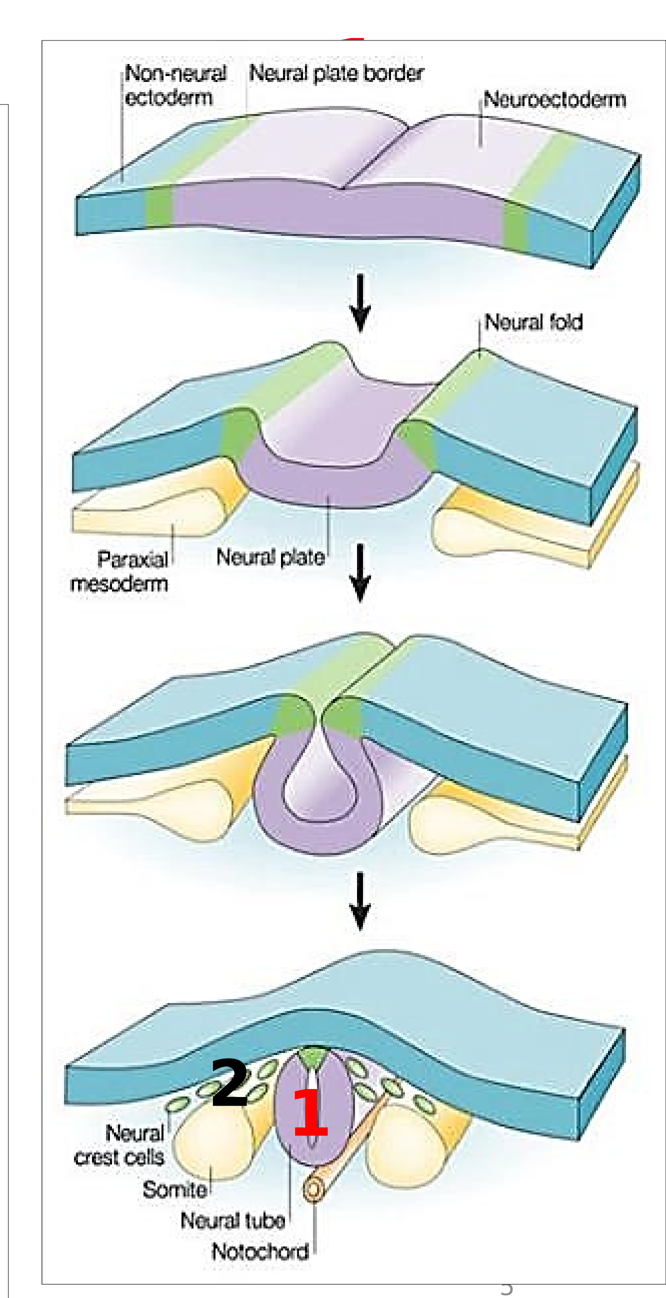
-Nervous system begins to develop during 3rd week.

-The whole nervous system is derived from <u>ectoderm</u> (neuroectoderm) except the microglia & dura mater which are mesodermal.

■The neuroectoderm includes:

1.Neural plate ⇒ Neural tube ⇒ CNS (brain & spinal cord) + part of the PNS (all motor & preganglionic autonomic nerves).

2.Neural crest ⇒ Part of the PNS (sensory ganglia &



https://www.nature.com/articles/nrn1219/figures/1

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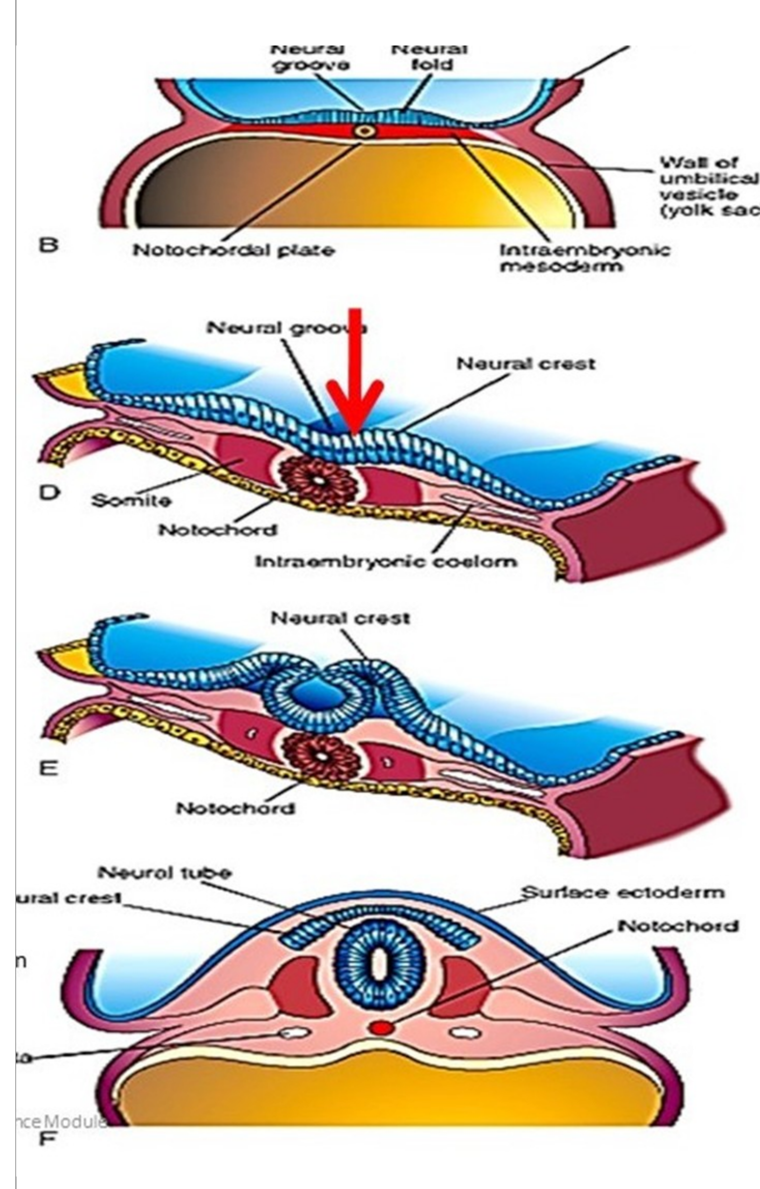
♣Formation of the neural tube [Neurulation]:

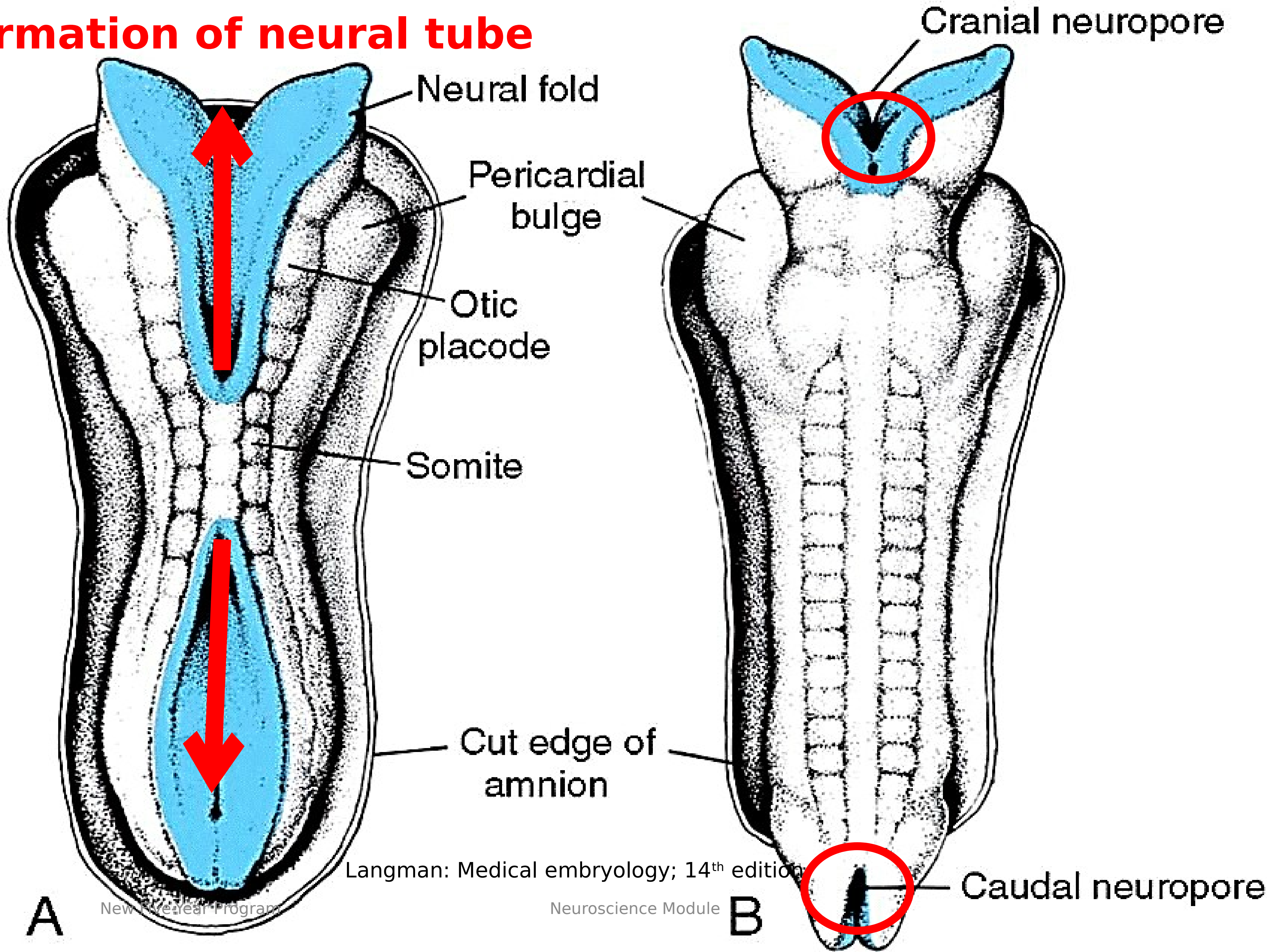
-During 3rd week, the notochord & the paraxial mesoderm <u>induce</u> the overlying ectoderm to differentiate into the neural plate ⇒ Neural groove.

-Neural folds (edges of the groove) approximate & fuse together in midline ⇒ Neural tube.

-Fusion begins at cervical region and proceeds both cranially & caudally.

-Cranial (anterior) neuropore closes on the 25th day; the caudal neuropore closes 2 days later




rmation of neural tube
Neural fold
Pericardial bulge
Otic placode
Somite
Cut edge of amnion
Cranial neuropore
Caudal neuropore
A
B
Langman: Medical embryology; 14th edition

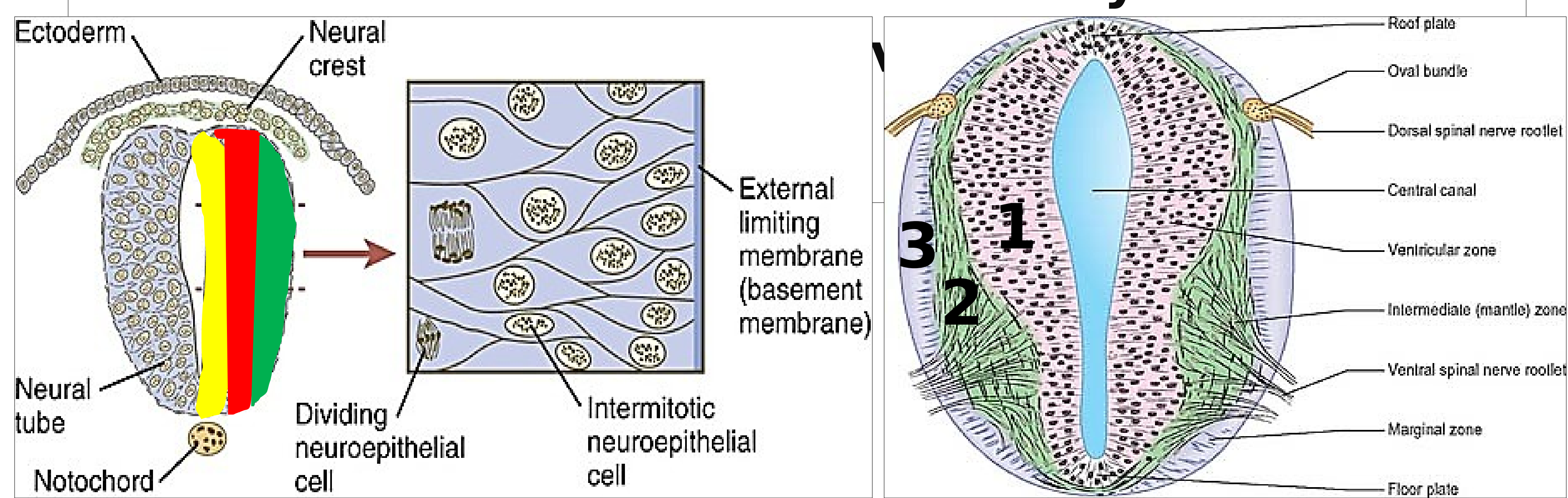
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♣Histogenesis (cytogenesis) of the neural tube:

-At first, wall of the neural tube is a single layer of columnar cells that differentiate into 3 zones:

1.Inner ependymal (ventricular or germinal) zone ⇒ Lining of the central canal & ventricles.

2.Intermediate mantle zone ⇒ Gray matter.

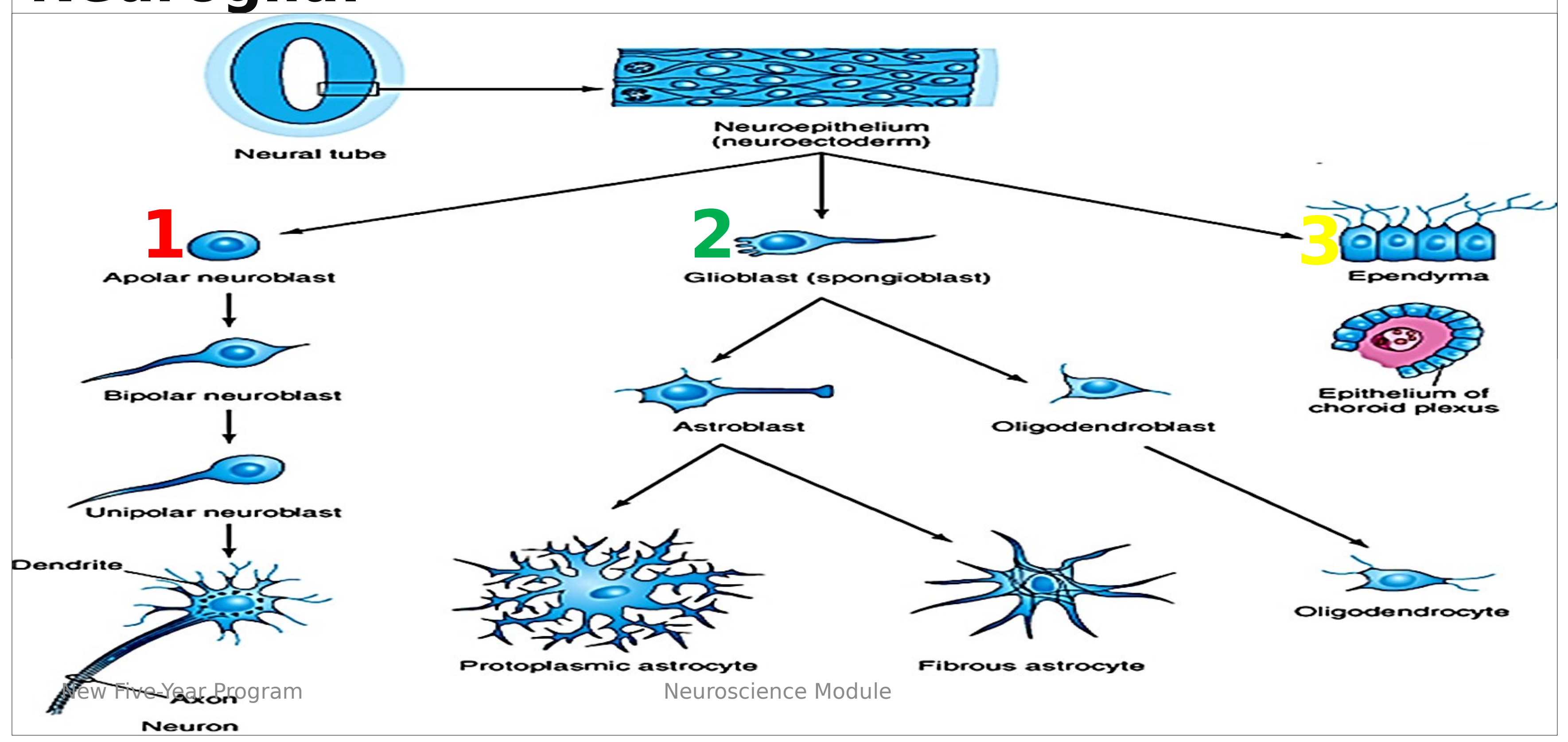


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-The cells in the mantle zone differentiate into 2 types:

1. Neuroblasts (= young nerve cells) ⇒ Neurons.

2. Glioblasts (= young neuroglia cells) ⇒ Neuroglia.



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● **Myelination of nerve fibers**:

-Starts in <u>4th month</u> and is not completed till 2nd year after birth.

-Myelination of motor fibers occurs <u>earlier</u> than sensory fibers.

-Myelination in CNS is by oligodendroglia while outside CNS is by Schwann cells (derived from the neural crest).



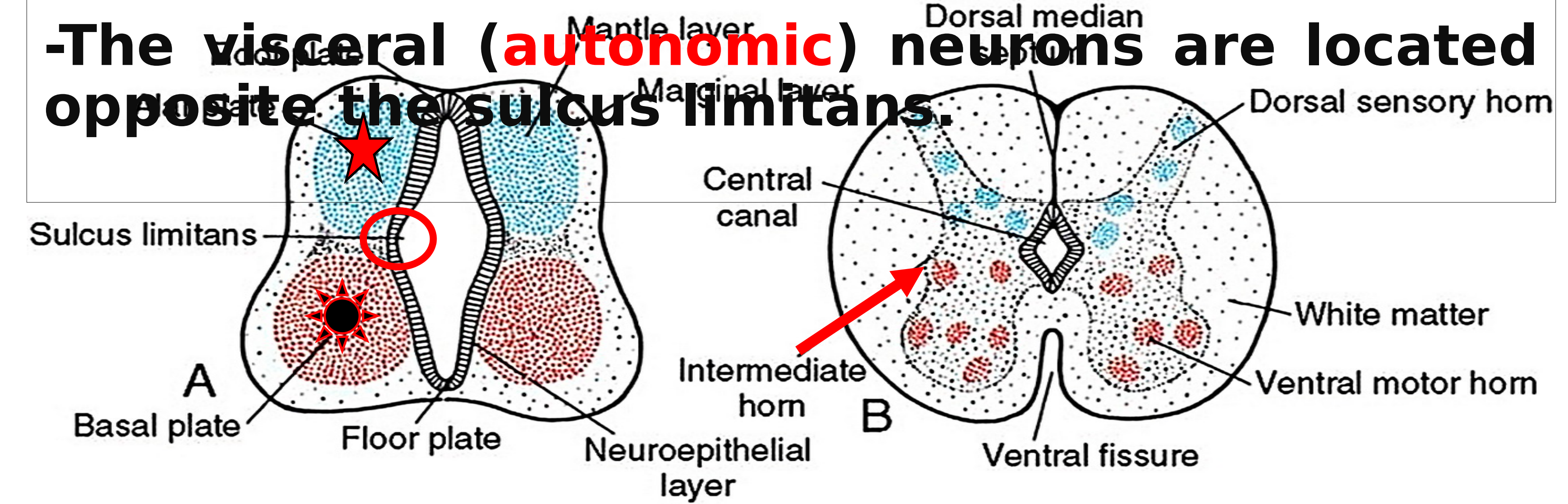
♣Fate of the neural tube:

-A shallow longitudinal groove, the **sulcus limitans** divides the mantle layer on each side into:

-Dorsolateral lamina (**alar plate**) containing sensory neurons.

-Ventrolateral lamina (**basal plate**) containing motor neurons.

-The visceral (**autonomic**) neurons are located opposite the sulcus limitans.



Langman: Medical embryology; 14th edition

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Quiz

■Mention true ________________ each statement regarding formation of the neural tube:

a. Neural plate develops under the inductive influence of both notochord & paraxial mesoderm.

b. Caudal neuropore closes 2 days earlier than cranial one

T – F

▪What is the time for myelination of nerve fibers? Mention the responsible cells for myelination in both CNS & outside CNS

♣Development of the spinal cord:

-It develops from caudal part of the neural tube. ***Caudal to 4th pair of somites***

-The lumen ⇒ Central canal.

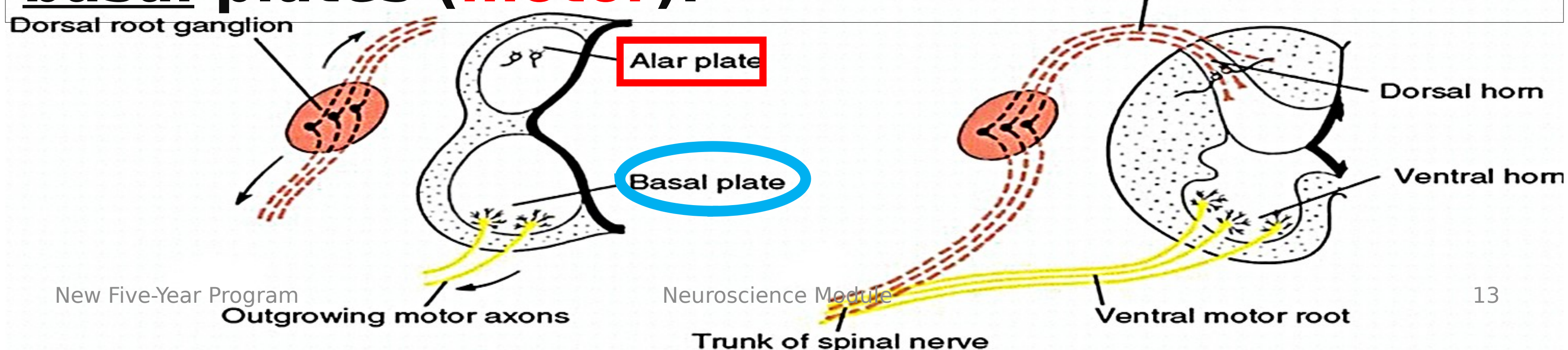
- Lateral wall: 3 zones;

.Ependymal layer ⇒ Lining of central canal.

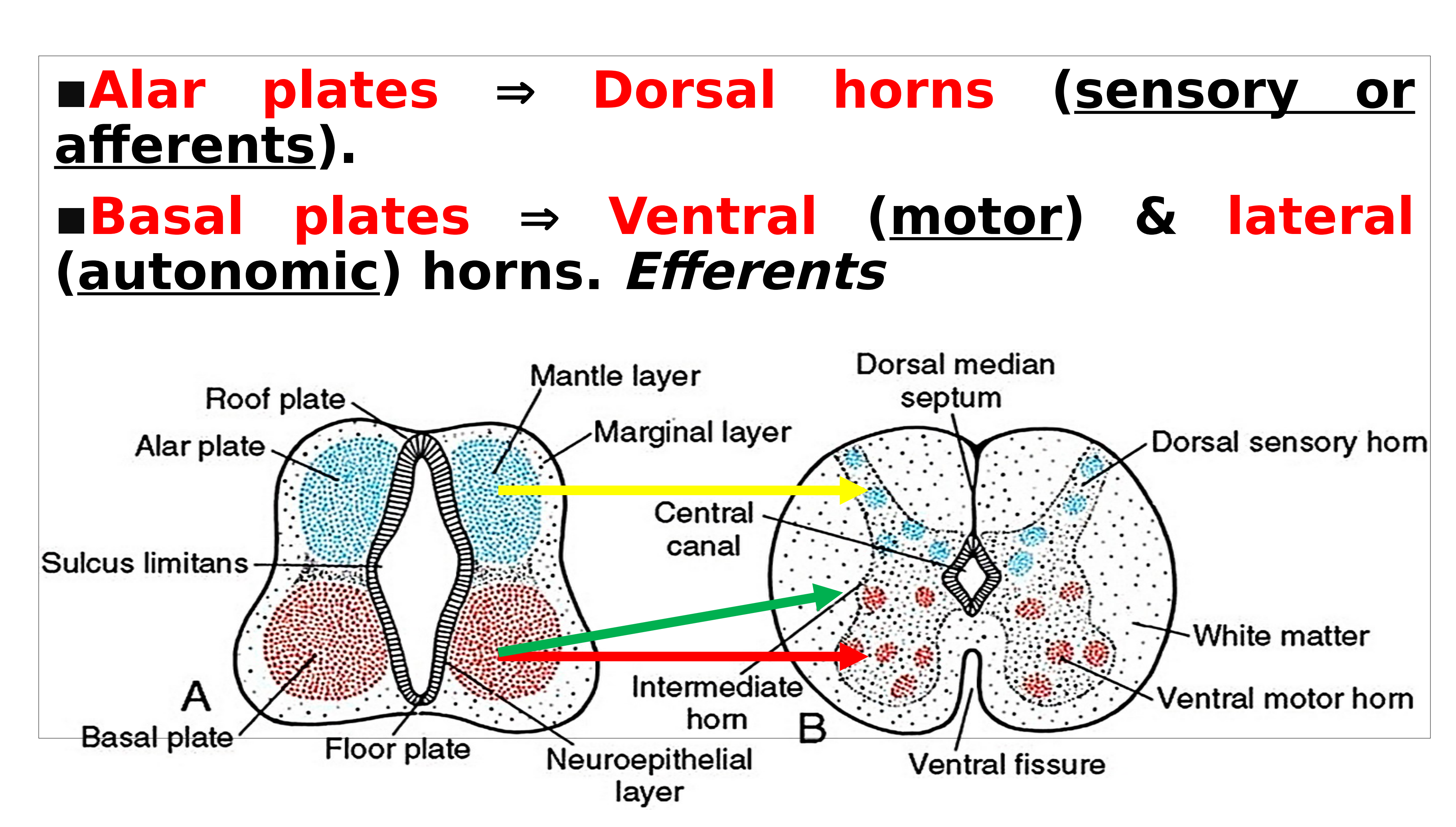
.Mantle layer ⇒ Grey matter.

.Marginal layer ⇒ White matter.

-Sulcus limitans divides mantle layer on each side into dorsal alar plates (sensory) & ventral basal plates (motor).



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■**Alar plates ⇒ Dorsal horns (<u>sensory or afferents</u>).**

■**Basal plates ⇒ Ventral (<u>motor</u>) & lateral (<u>autonomic</u>) horns. *Efferents***

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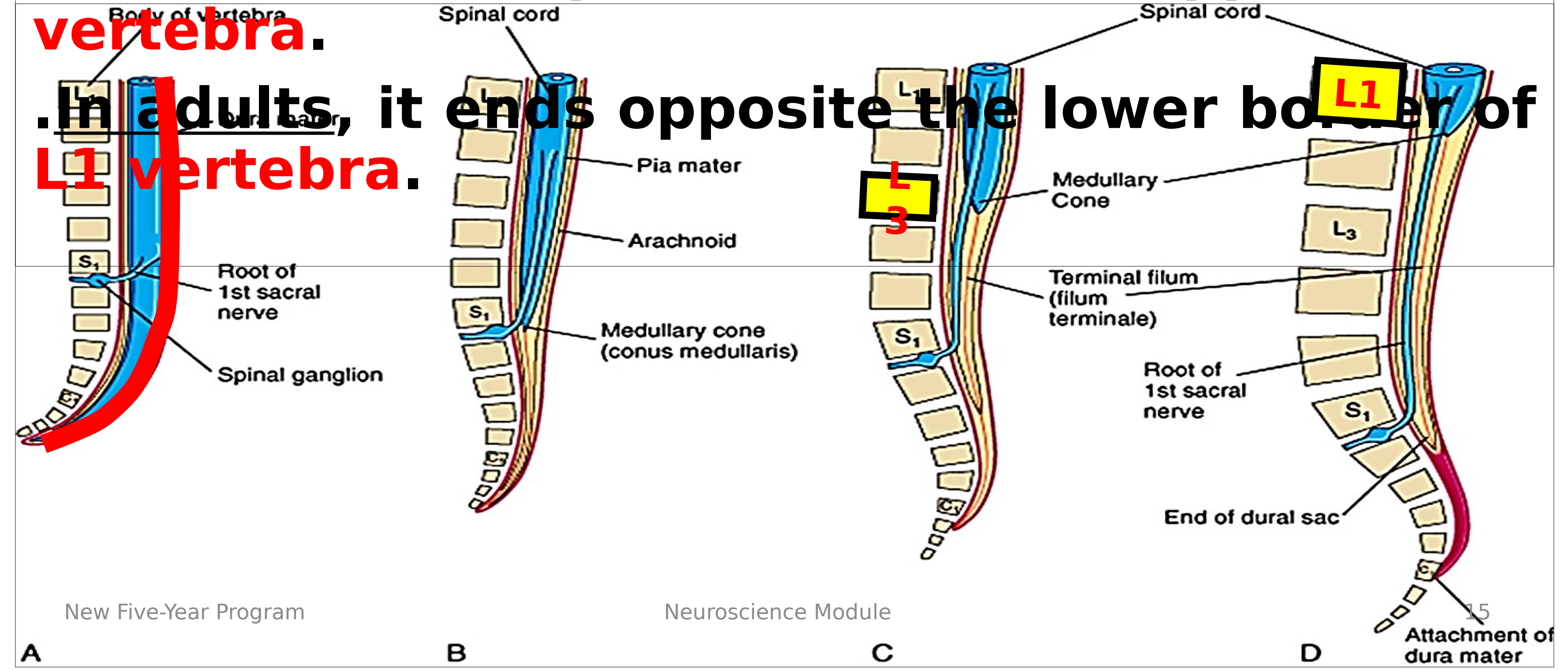
●Positional changes of spinal cord during its development:

-In **3rd month** of intrauterine life, the spinal cord fills the vertebral canal completely.

-Later, the vertebral canal & dura elongate **faster** thus:

.**At birth**, the spinal cord ends opposite **L3 vertebra**.

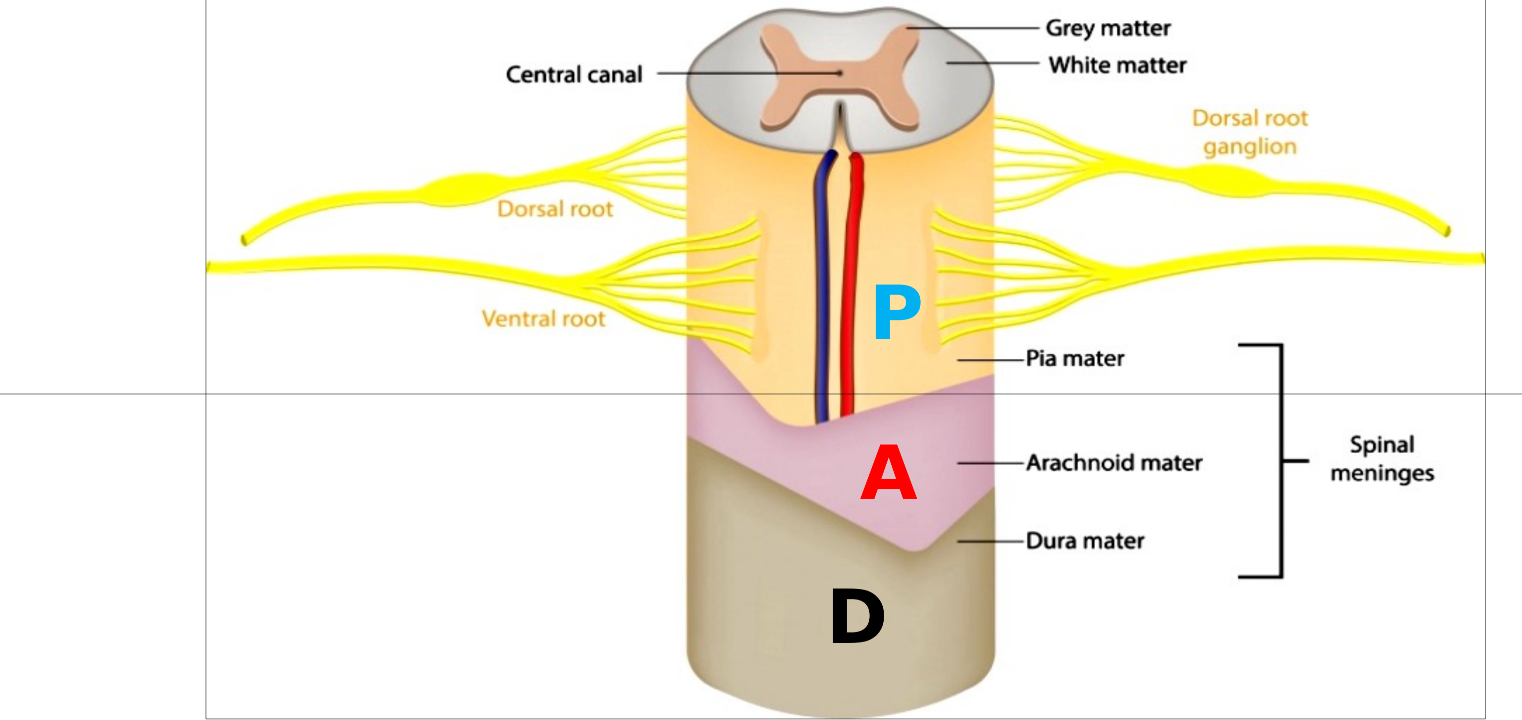
.**In adults**, it ends opposite the lower border of **L1 vertebra**.



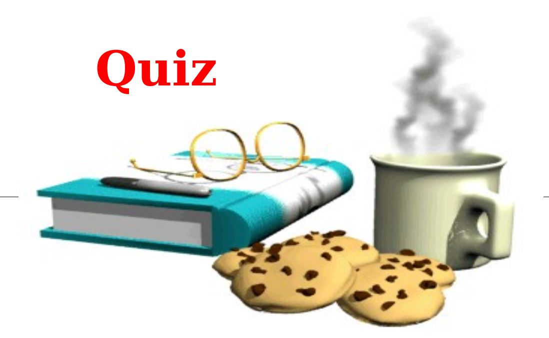
● Development of the spinal meninges:

-The dura mater is mesodermal from mesenchyme around neural tube.

.The internal leptomeninges (pia & arachnoid) are derived from neural crest cells (ectodermal).



Quiz



- **What is the fate of both alar plate & basal plate during development of the spinal cord?**
- **At which vertebral level does spinal cord end at time of birth?**

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♣**Congenital anomalies of the spinal cord**:

-Most congenital anomalies of spinal cord result from defective closure of neural tube during 4th week → Neural tube defects (NTDs). Diagnosed by ↑ level of *alpha fetoprotein* during amniocentesis. *Risk can be decreased by folic acid supplements*

■**Spina bifida (1/1000 of population):**

-Failure of fusion of the vertebral arches, leaving a midline defect usually at L5-S1.

-There are 2 types:

1. Spina bifida occulta: Asymptomatic; may be marked externally by tuft of hair. *Just midline bony defect diagnosed radiologically*

2. Spina bifida cystica: Much more serious. May be:

-Meningocele: Meninges covered by skin bulge

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Spina bifida

Hairs
Dura
Skin
Arachnoid
Arachnoid
Subarachnoid space
Spinal cord
Transverse process
Dura

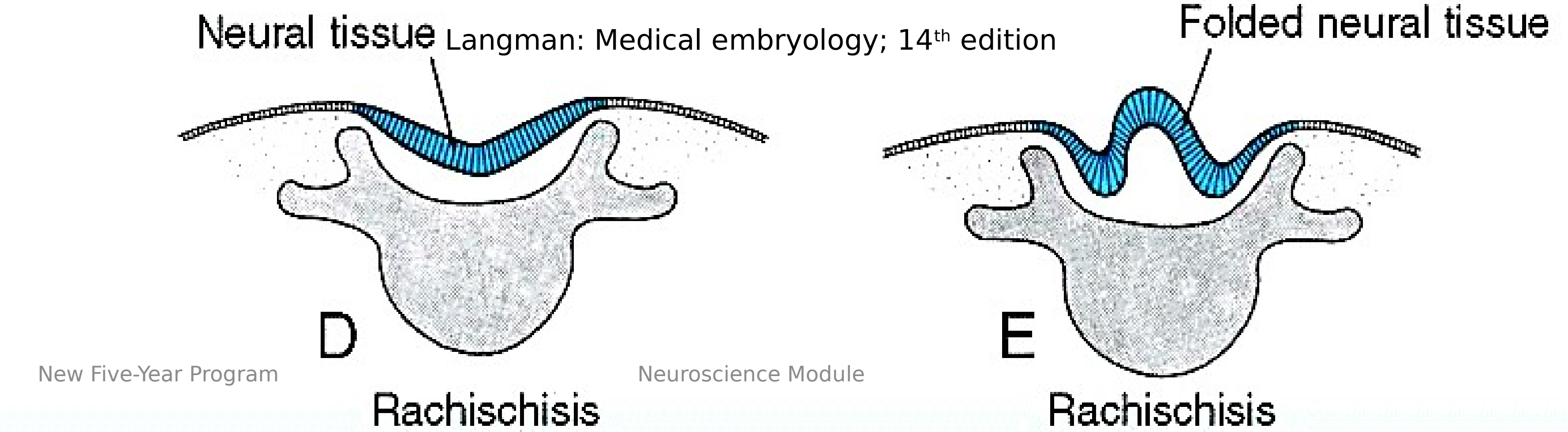
A
Spina bifida occulta

B
Meningocele

Cystica

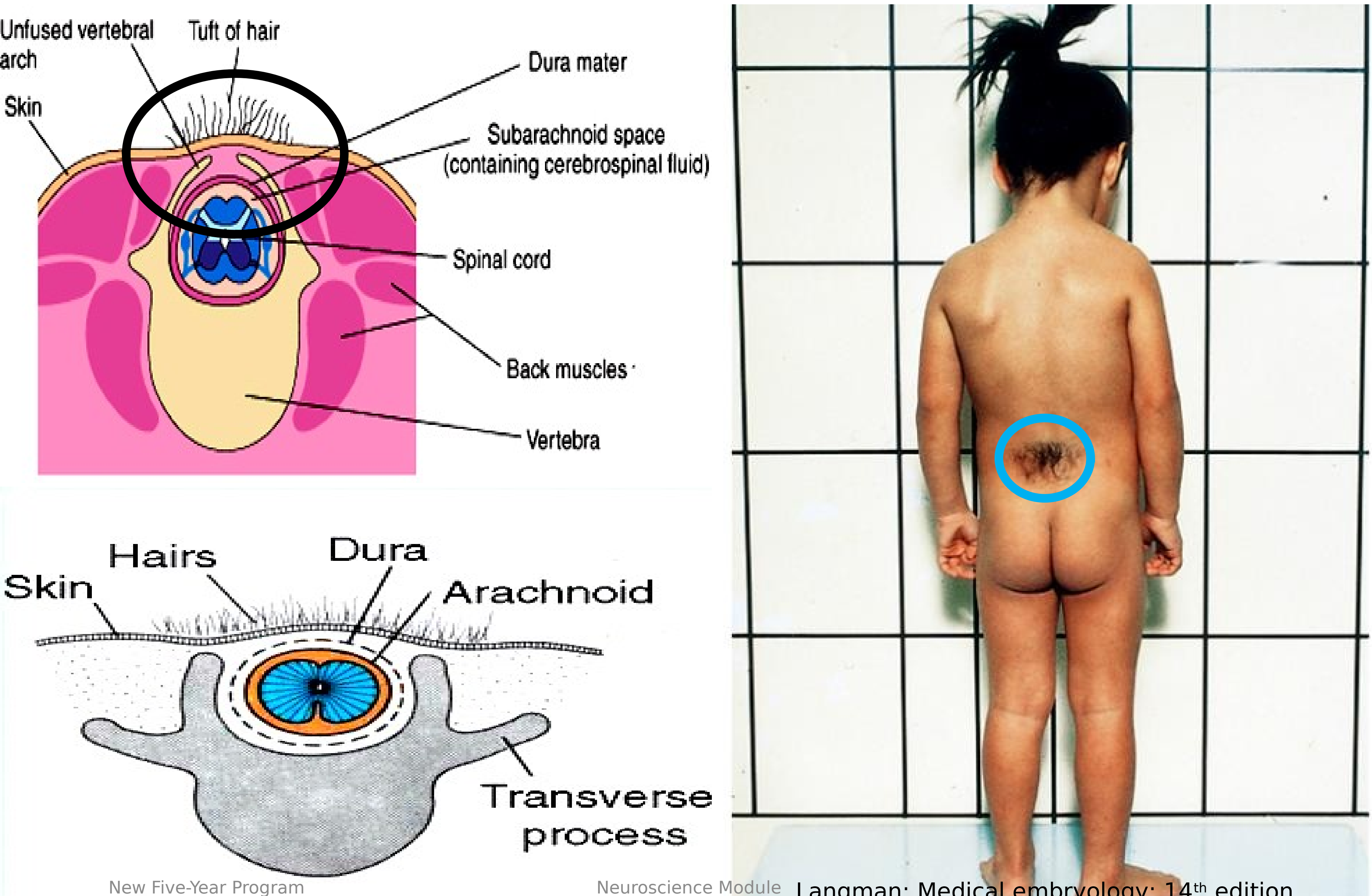
C
Meningomyelocele

Langman: Medical embryology; 14th edition



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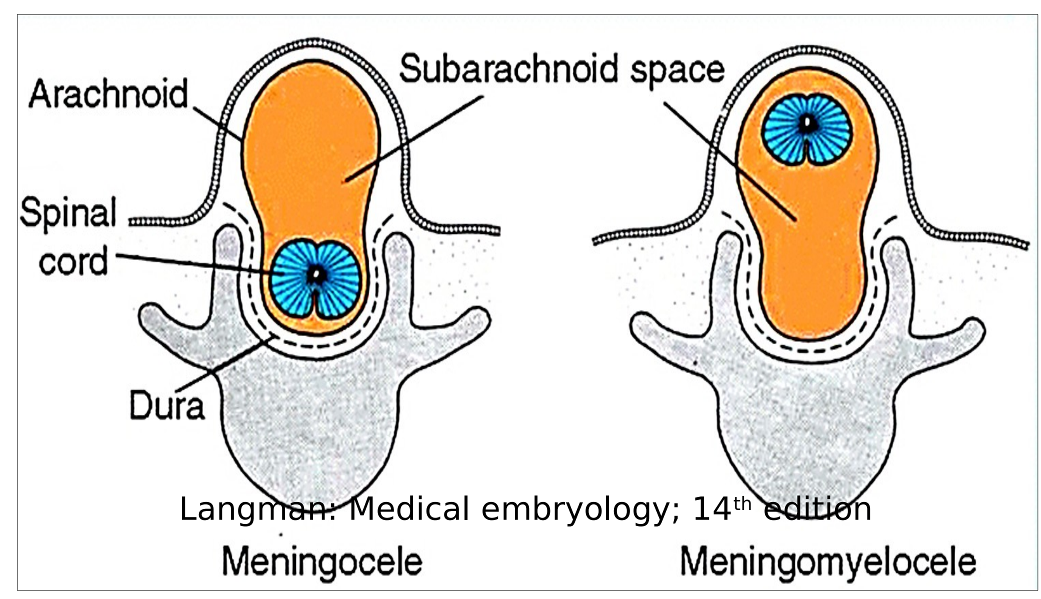
Spina bifida occulta

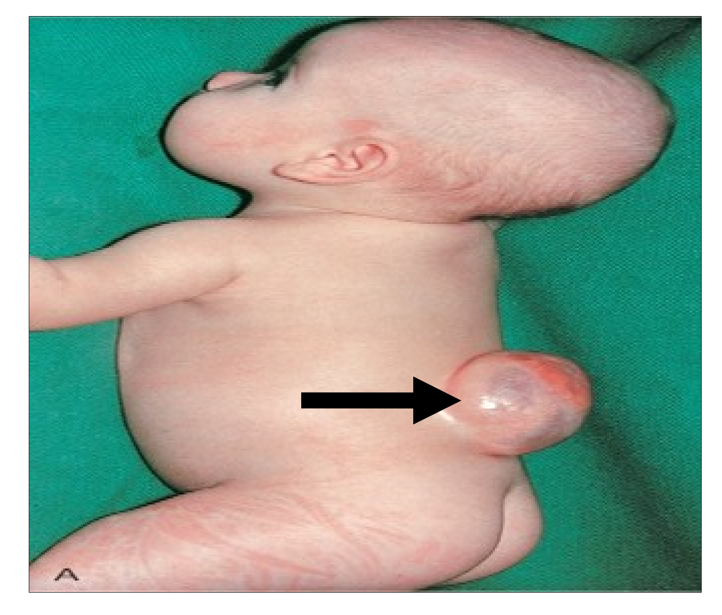


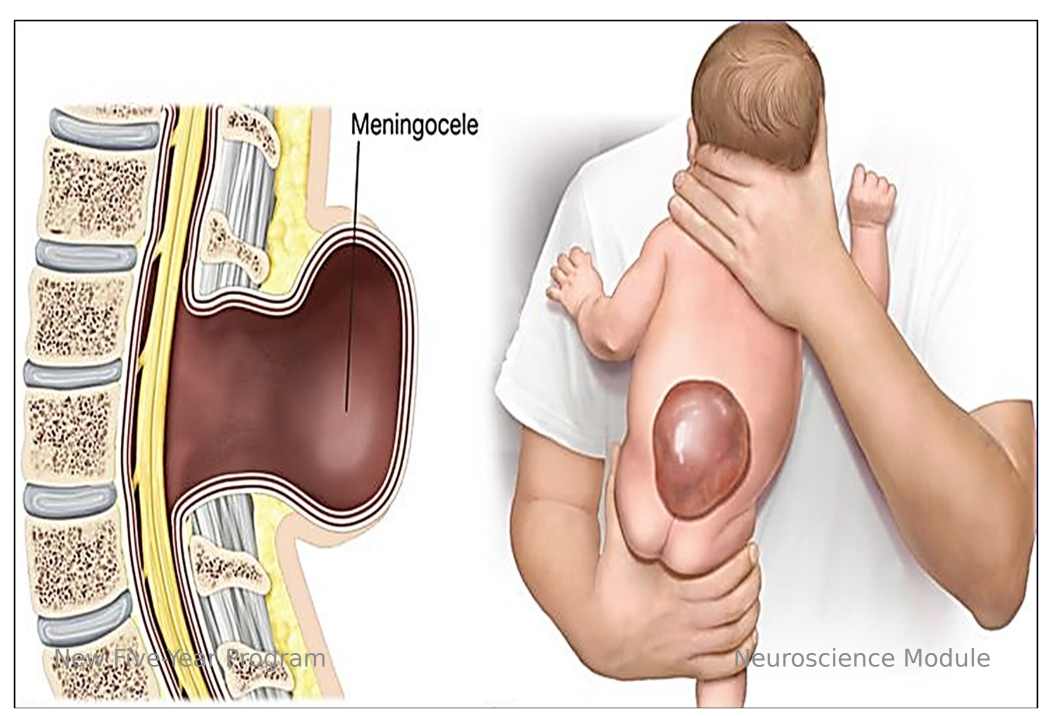
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Spina bifida cystica







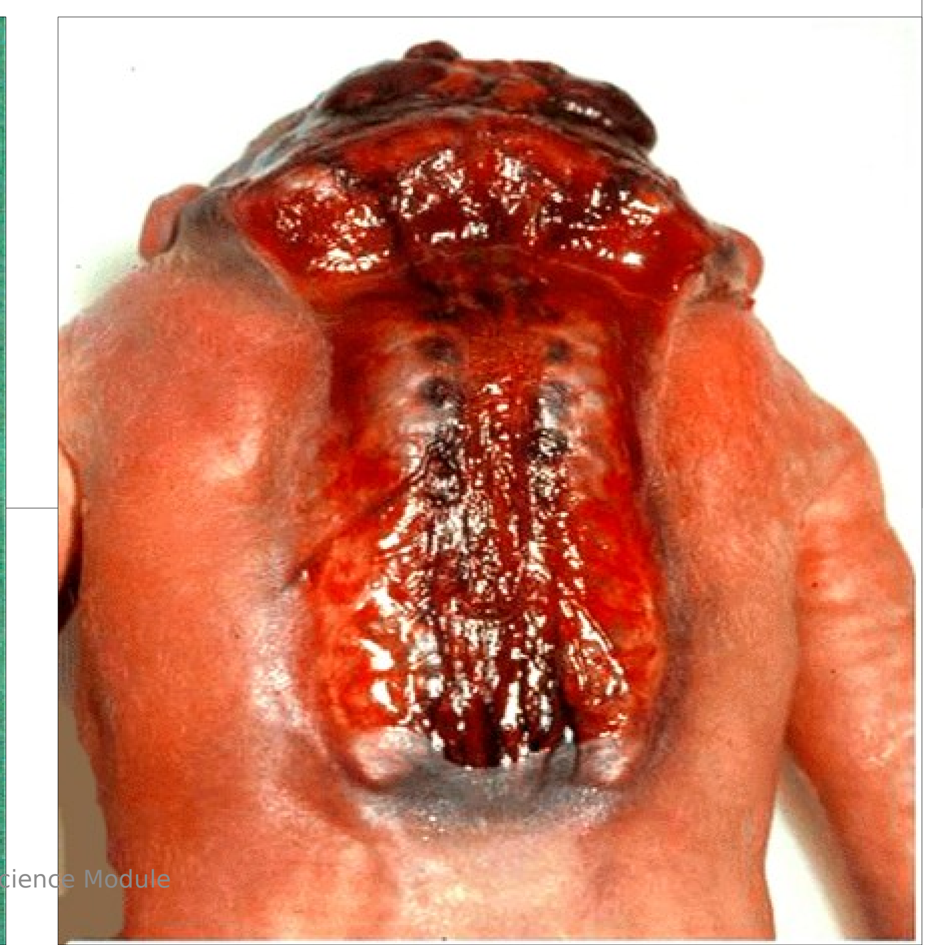


3. Myeloschisis or Rachischisis:

-This is the most severe type of spina bifida.

-Neural tube is not closed & nervous tissue is exposed to the surface.





♣**Development of the brain**:

-It develops from neural tube cranial to the 4th pair of somites.

-3 primary brain vesicles develop in the cranial part of neural tube. From cranial (rostral) to caudal, they are:

1.Forebrain (Prosencephalon).

2.Midbrain (Mesencephalon).

3.Hindbrain (Rhombencephalon).

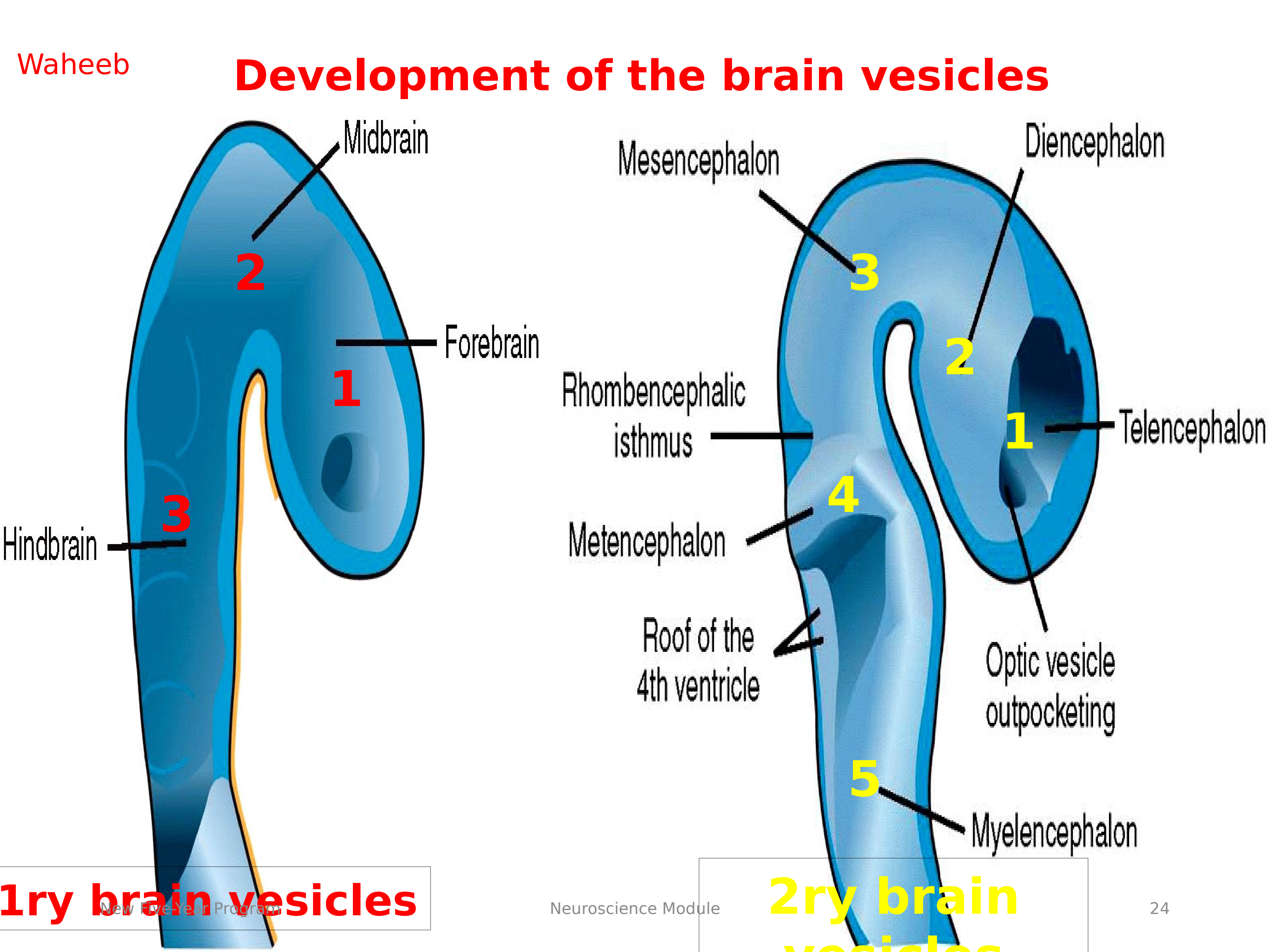
-During 4th week, forebrain partially divides into 2 secondary brain vesicles, the telencephalon& diencephalon.

-By 5th week, hindbrain gives rise to the metencephalon& the myelencephalon.

.Thus, 5 secondary brain vesicles are developed.

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Development of the brain vesicles



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.3 Primary brain vesicles ⇒ 5 secondary brain vesicles ⇒ Adult derivatives

1rv vesicle	2rv vesicle	Adult	Cavity
Forebrain (Prosencephalon)	Telencephalon	Cerebral hemispheres *Retina & Optic N.*	Lateral ventricles
	Diencephalon	Thalamus, Hypothalamus, Pineal	3rd ventricle
Midbrain (mesencephalon)		Midbrain	Cerebral aqueduct

Hindbrain (Rhombencephalon)	**Metencephalon**	**Pons & Cerebellum**	**4th ventricle**
	Myelencephalon	**M.O**	

3 Primary vesicles
Wall
Cavity
1
2
3
Forebrain (prosencephalon)
Midbrain (mesencephalon)
Hindbrain (rhombencephalon)
5 Secondary vesicles
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
1
2
3
4
5
Spinal cord
Adult derivatives of
Walls
Cavities
Cerebral hemispheres
Lateral ventricles
Thalami, etc.
Third ventricle*
Midbrain
Aqueduct
Pons
Upper part of fourth ventricle
Cerebellum
Medulla
Lower part of fourth ventricle

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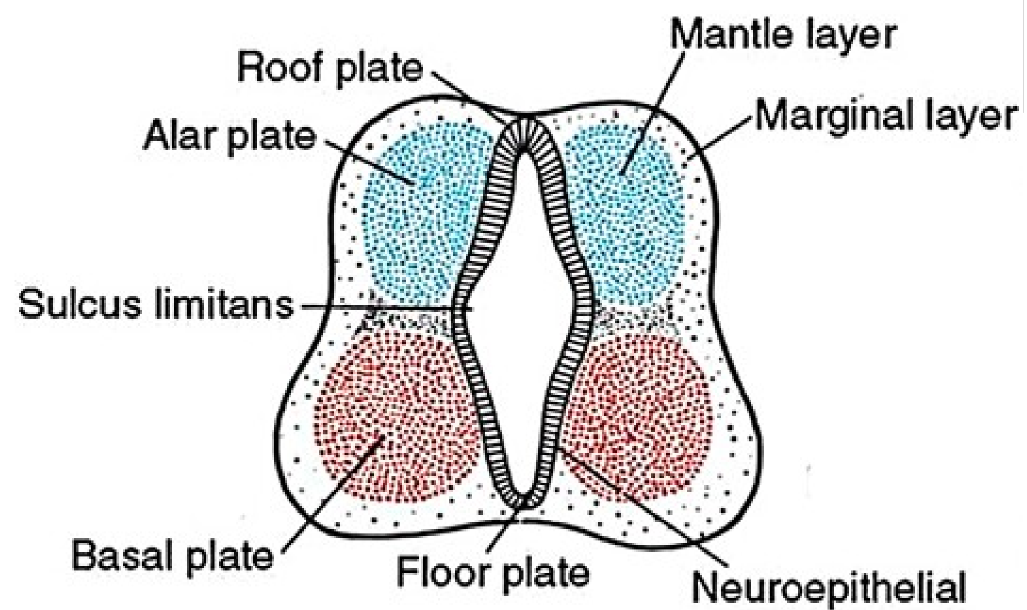
Don't forget:

Neural tube has a lumen or cavity & its wall is divided into 2 plates on each side:

-Basal plate (Motor)

-Alar plate (Sensory)

-The 2 plates are separated by sulcus



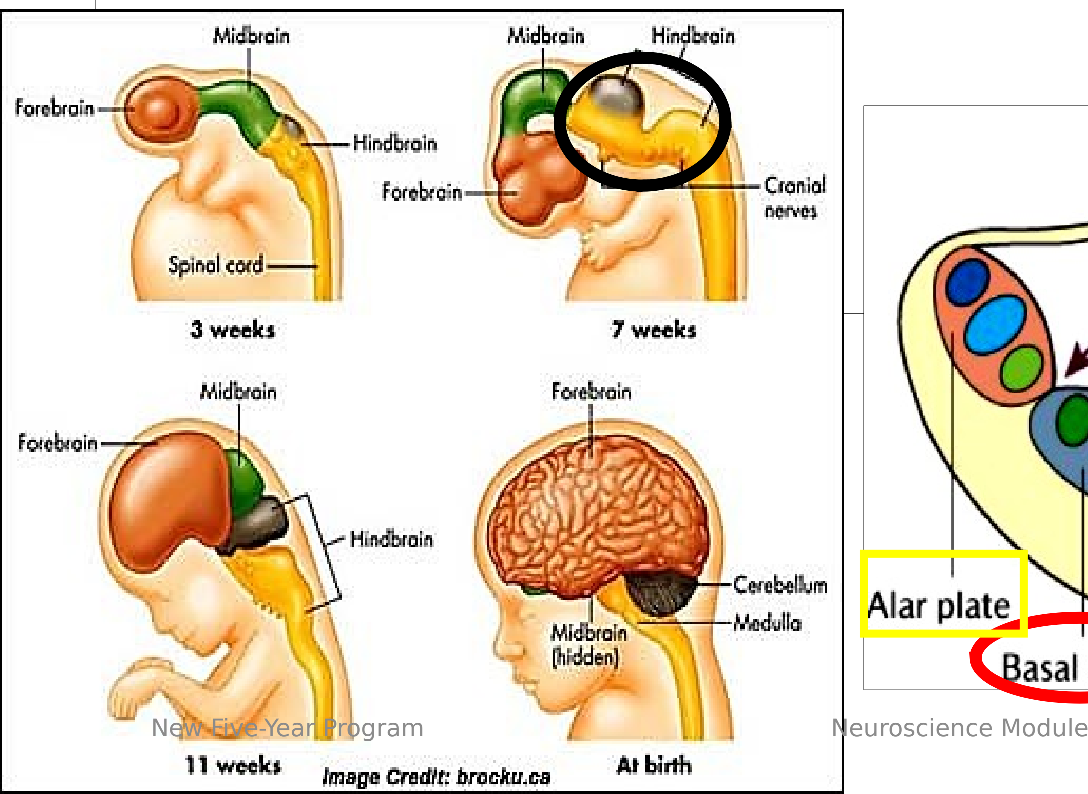
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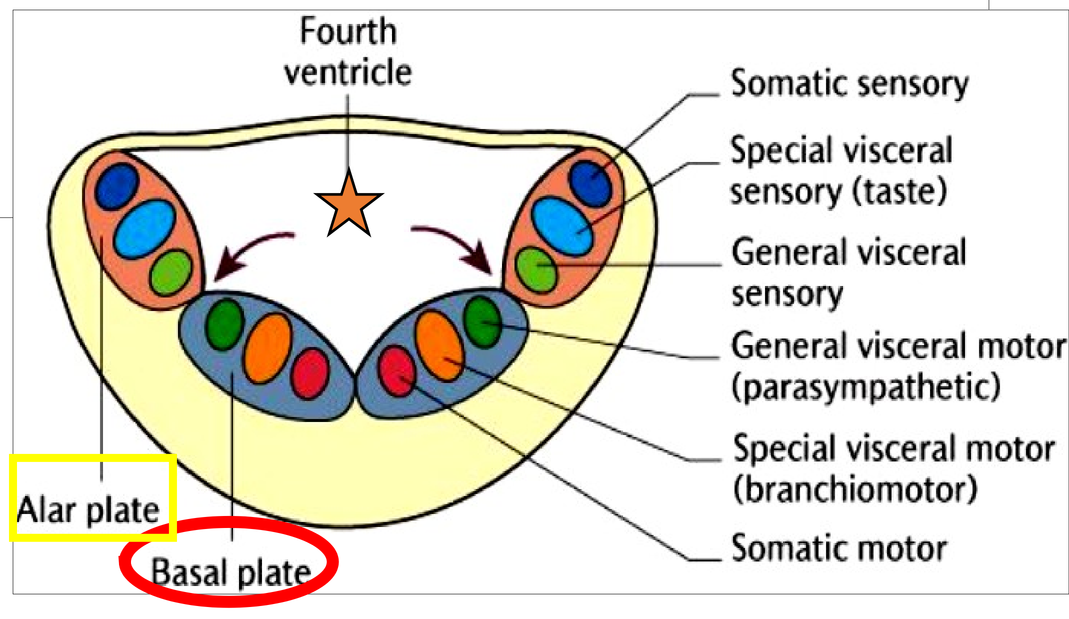
●**Hindbrain vesicle (Rhombencephalon):**

.Myelencephalon ⇒ Medulla oblongata (MO) & Metencephalon forms the pons& cerebellum.

-The cavity dilates forming the 4th ventricle.

-Basal plate (motor) becomes medial & alar plate (sensory) becomes lateral ⇒ *Cerebellum*





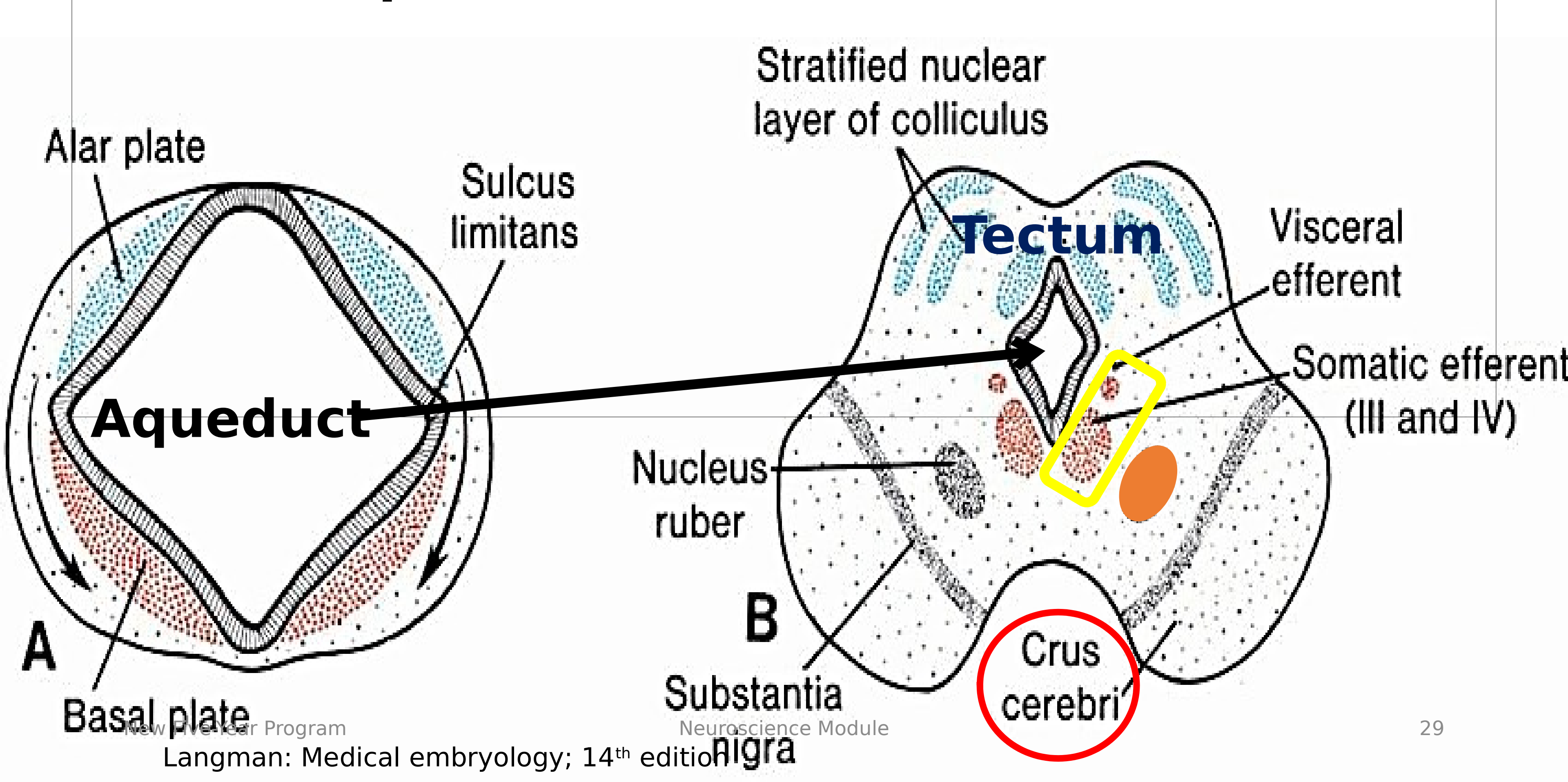
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- **Midbrain vesicle (Mesencephalon) ⇒ Midbrain**

-Its cavity ⇒ Cerebral aqueduct

-Its alar plate ⇒ The tectum

-Its basal plate ⇒ Crus cerebri & nuclei. *Motor*



Langman: Medical embryology; 14th edition

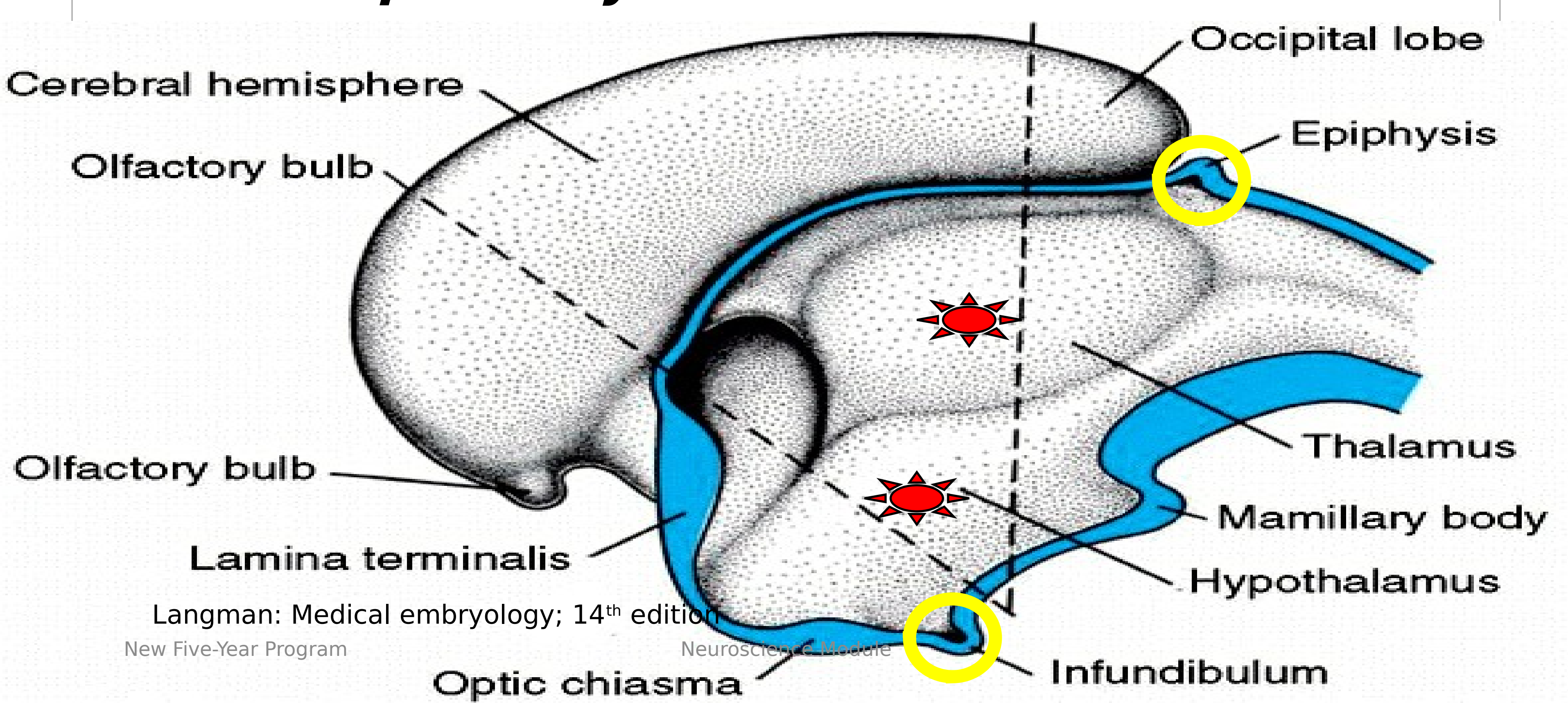
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●**Forebrain vesicle (Prosencephalon):**

.Diencephalon:

-Its cavity ⇒ 3rd ventricle.

-It has only 2 alar laminae which gives <u>thalamus</u> & <u>hypothalamus</u>. *Pinal body & Posterior pituitary*

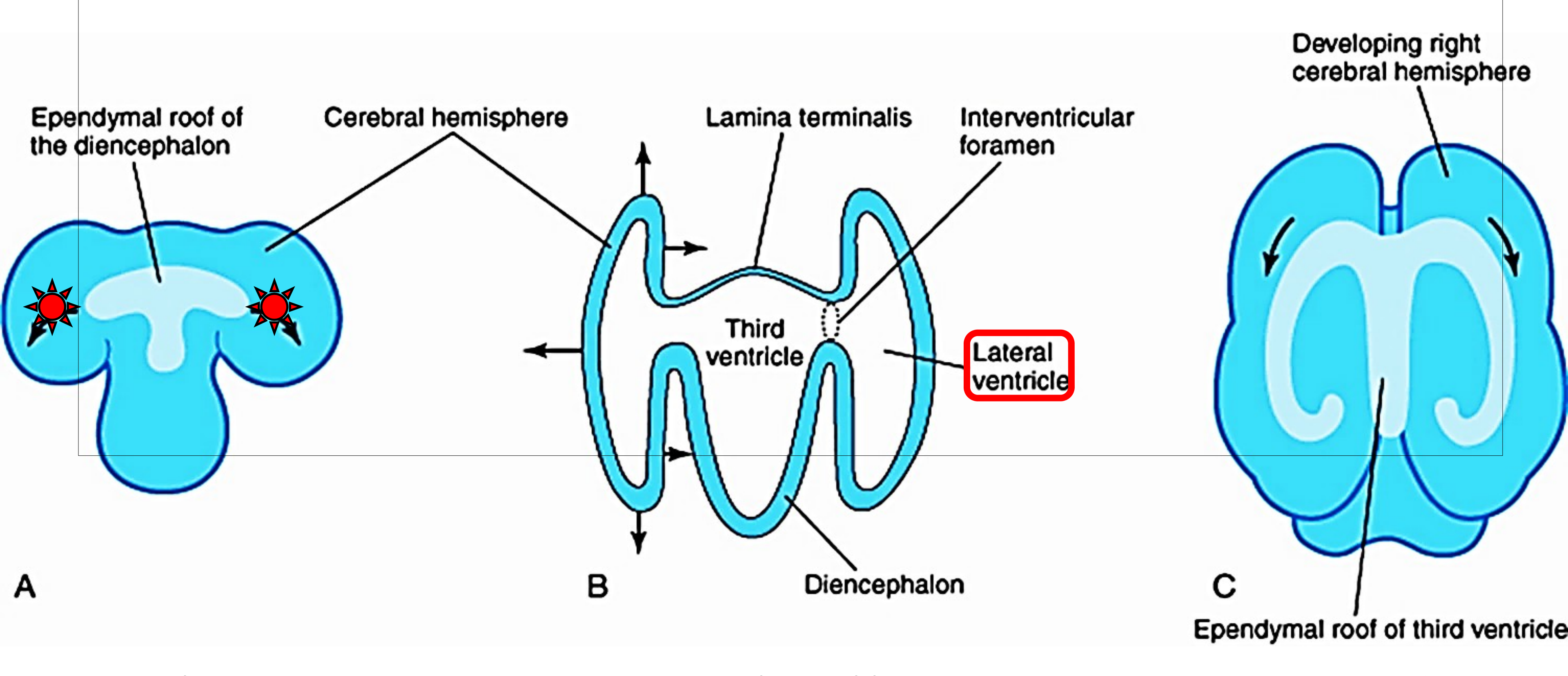


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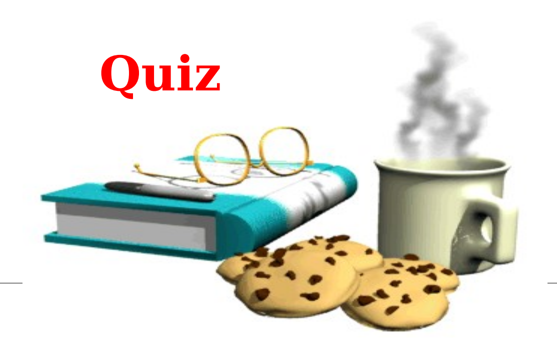
.**Telencephalon**: **Expands to form the cerebral hemispheres on each side.** ***Retina & optic N.***

-Its cavity forms the 2 lateral ventricles.



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Quiz



▪Mention <u>true or false</u> for each statement regarding formation of the neural tube:

a. Developing brain vesicles include 3 1ry & 5 2ry vesicles ◯◯

d. Thalamus develops from alar lamina of diencephalon ◯◯

T – T

▪List derivatives of both metencephalon & telencephalon. What are their cavities?

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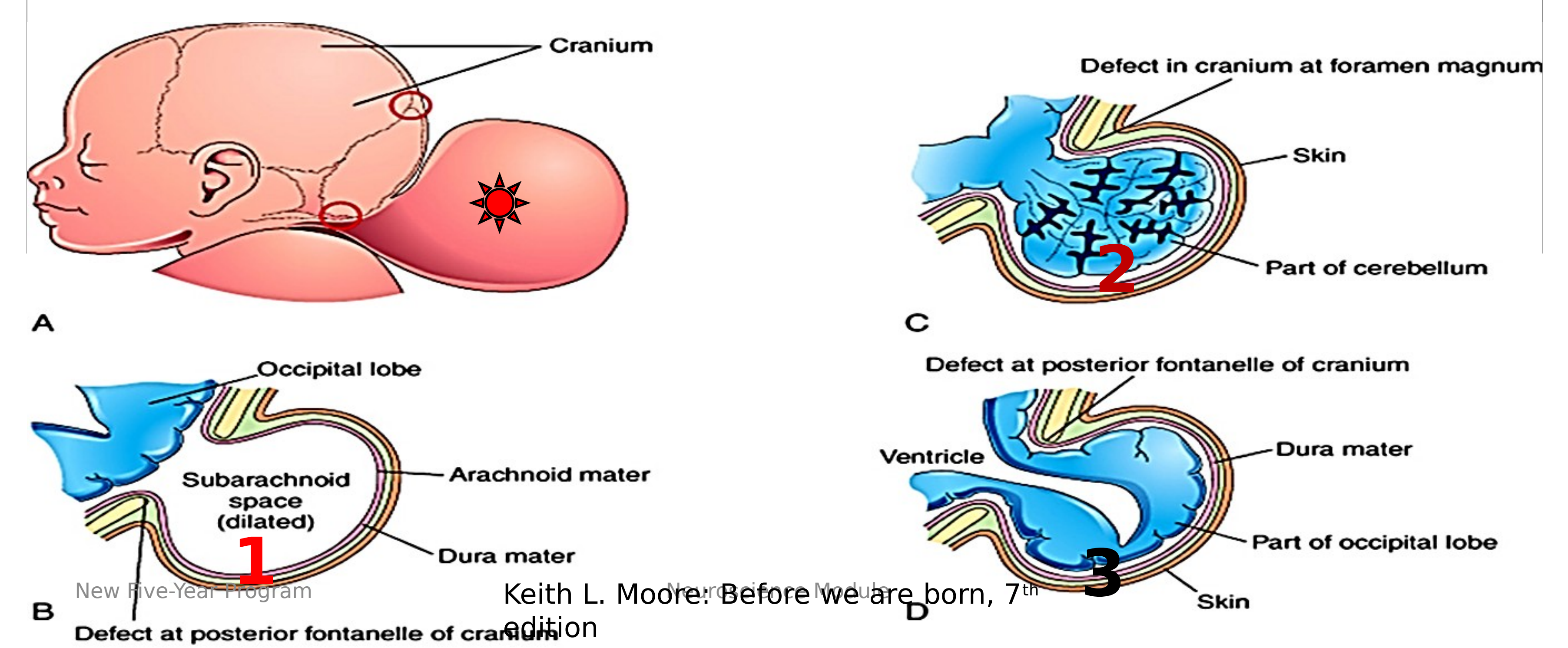
♣Congenital anomalies of the brain:

1.Skull defect through which meninges / brain herniate; mostly seen in the occipital bone

a. Cranial meningocele: *Meninges*.

b. Meningo-encephalocele: *Meninges & brain*.

c. Meningo-hydro-encephalocele: *Meninges, brain & ventricles*.



Keith L. Moore: Before we are born, 7th edition

Meningoencephalocele

A

B

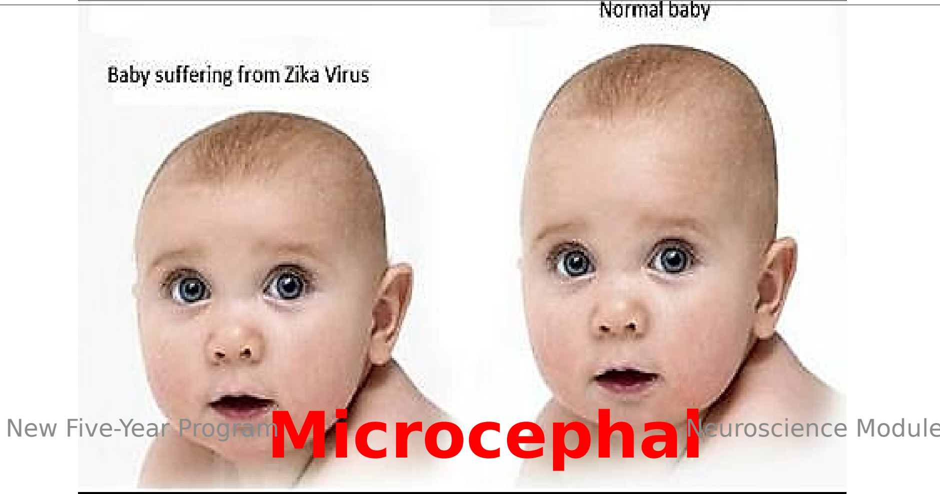
MRI of meningoencephalocele

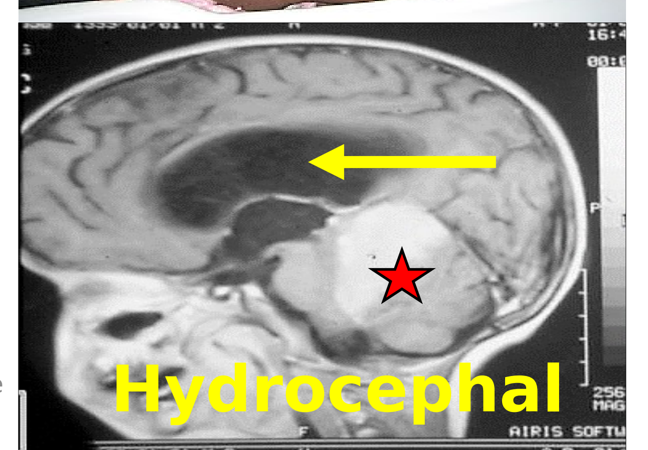
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2.**Microcephaly****: Small cranium due to impaired growth of brain.**

3.Hydrocephalus: Enlargement of the ventricles due to overproduction or obstruction to the flow of CSF as in congenital stenosis of the aqueduct or the foramina of the 4th ventricle. *Or tumors*







4.Anencephaly: Absence of skull cap with exposed brain due to failure of the anterior (cranial) neuropore to close [NTDs]; in most cases, the hindbrain remains intact. It causes hydramnios & is incompatible with life.



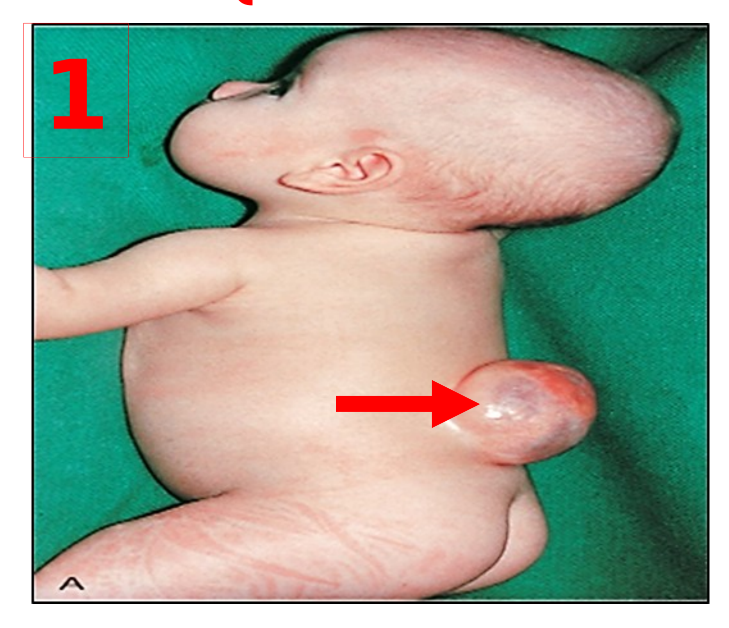


Anencephaly

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Quiz

Identify the anomaly







♣Neural crest cells:

-They are derived from the edges of neural folds & migrate to give rise to most of the peripheral nervous system (PNS).

-Derivatives:

1.Sensory ganglia of cranial nerves (5, 7, 9 & 10).

2.Sensory ganglia (DRG) of all spinal nerves.

3.Autonomic ganglia (sympathetic & parasympathetic).

4.Adrenal medulla.

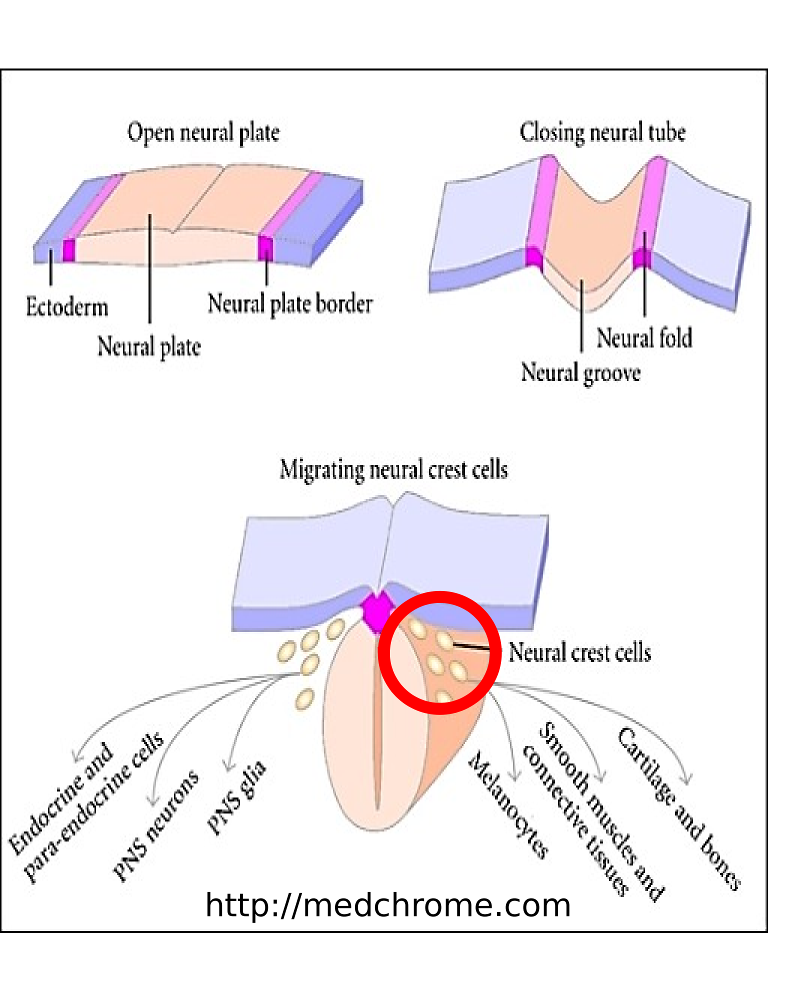
5.Neurilemmal (Schwann) cells for myelination of peripheral Ns.

6.Melanocytes → Skin.

7.Wandering NC cells which form the autonomic tissues in association with the digestive system & CVS.

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Derivatives of the neural crest



Neural crest
Neural crest cells
Neural crest cells
Neural tube
Dorsal gray horn
Spinal cord
Dorsal root
Spinal ganglion
Site of lateral gray horn
Ventral gray horn
Unipolar neuron (spinal ganglion cell)
Satellite cell
Schwann cell (of neurolemmal sheath)
Spinal nerve
Ventral root
White communicating ramus
Multipolar neuron (sympathetic ganglion cell)
Melanocyte
Ganglion of sympathetic trunk
Celiac ganglion
Plexus in intestinal tract
Renal ganglion
Suprarenal gland
Suprarenal medulla (chromaffin cells)

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Quiz

- **One the following structures is <u>not</u> a derivative of the neural crest:**

a. Trigeminal ganglion

b. Dura matter *

c. DRG

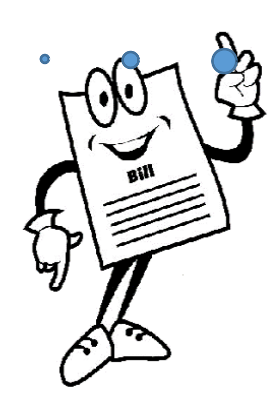
d. Schwann cells

e. Adrenal medulla

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Lecture Summary





Developme nt of nervous

-During 3rd week, the notochord & the paraxial mesoderm induce the overlying ectoderm to differentiate into the neural plate ⇒ Neural groove ⇒ Neural tube

-The neural tube; its cranial part expands to form the brain & its narrow caudal part forms the spinal cord. *4th pairs of somites*

-Remember that, alar plates are sensory while basal plates are motor

-Remember congenital anomalies of the spinal cord (e.g. meningocele) and their explanation

-The brain has 3 primary & 5 secondary brain vesicles that develop during 4th & 5th weeks. Remember their derivatives & cavities.

-Also, remember congenital anomalies of the brain (e.g. anencephaly) and their

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SUGGESTED TEXTBOOKS



1. **Keith L. Moore: Before we are born, essentials of embryology and birth defects; 7th edition.**
2. **Langman: Medical embryology; 14th edition.**
3. **Web sites: https://studentconsult.inkling.com**
   https://www.clinicalkey.com/student



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